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Coastal wetland area change for two freshwater diversions in the Mississippi River Delta

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ABSTRACT

Coastal systems around the globe are being re-integrated with adjacent river systems to restore the natural hydrologic connection to riparian wetlands. The Mississippi River sediment diversions or river reconnections are one such tool to combat high rates of wetland loss in coastal Louisiana, USA by providing freshwater, sediment, and nutrients. There has been some disagreement in the published literature whether re-establishing river reconnection is slowing or contributing to coastal wetland loss. This issue is due to the difficulties in the application of remote sensing in low-relief environments where water level changes could indicate either land loss or simply temporary submergence. We analyzed land change at the receiving areas of two existing freshwater river diversions, Davis Pond and Caernarvon, which have been intermittently receiving river water for up to 2+ decades. This study provides a robust analysis of wetland land change rates in proximity these river diversions including years before river reconnection. Our analyses indicate a net land gain since river reconnection operations began at Davis Pond Diversion (+3.42 km^2; range: +2.02–4.81 km^2) and no statistically significant change at the Caernarvon Diversion. The Davis Pond wetland results are corroborated with data from a decadal field study documenting increased inorganic sedimentation in the soil. It is clear from this study and others, that river reconnection can increase or, in the case of Caernarvon, have no statistical effect on the land change in these systems due to differences in vegetation, hydroperiod, sediment delivery and external factors including hurricane impacts. Our remote sensing analysis was compared with a global water area change analysis mapping tool which also supported our findings.

1. Introduction

Wetlands maintain an elevation relative to local water level through a combination of organic matter accumulation and mineral sediment deposition (Delaune and Pezeshki, 2003; DeLaune et al., 2013; Roberts et al., 2015). Increasing eustatic sea level during the Holocene (Parkinson et al., 1994) and anthropogenic activities, including construction of river levees and flood control structures throughout major drainage basin, fundamentally changed critical components of the hydrologic and sediment supply equation to the world's deltas (Blum and Roberts, 2009; Day et al., 2007; Osorio et al., 2020). River sediment diversions are designed to restore some of that natural connectivity function of the riparian system by mimicking the natural process of crevasse splay formation associated with river deltas, while simultaneously maintaining flood control benefits to populated and developed areas (Peyronnin et al., 2017).

A recent paper (Turner et al., 2019) discusses patterns of wetland loss at two freshwater diversions at Davis Pond and Caernarvon in Louisiana, USA. The authors concluded that these diversions resulted in a net land loss after diversion implemented river reconnection and suggest their findings should cast doubt on the potential effectiveness of future planned large Mississippi River sediment diversions (e.g., Mid-Breton and Mid-Barataria). These sediment diversions have been authorized by the State of Louisiana and are in the design and permitting phase at present (CPRA, 2017). Concerns about river diversion-related inundation impacts are valid, as any significant alteration to hydrology could have unintended consequences for marsh success in the coastal receiving basin (Morris et al., 2002; Snedden et al., 2015; White et al., 2019). However, the finding presented by Turner et al. (2019) were affected by incorrectly applying an analysis to a data set that was clearly labeled as inappropriate for the task. In this study, we analyzed the Davis Pond and Caernarvon wetland areas pre and post river reconnection for land

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change using a more appropriate data set to determine coastal wetlands areal coverage change over time.

The authors would like to be clear that neither the Caernarvon nor Davis Pond diversions were primarily designed as sediment diversions while building and/or sustaining land was anticipated. Both were primarily designed as freshwater reintroductions to control the location of isohalines in the Breton Sound and Barataria interdistributary basins, respectively, to combat saltwater intrusion associated with rising relative sea levels and coastal subsidence. This premise is of vital importance, as freshwater diversions are 1) not preferentially located on sediment-rich river channel reaches, are 2) not designed to capture more sediment-rich water deeper in the river water column and 3) have not always operated in sync with periods when the river's suspended sediment load is high (e.g., the rising limb of the flood hydrograph) (Peyronnin et al., 2017). Further, ponding (receiving) areas were designated at the outlet of their conveyance channels to serve as locations to focus the sedimentation, which exclude them from nourishing the greater coastal wetland basin proper (Keogh et al., 2019). Nyman (2014) came to the same conclusion in a critique of an earlier paper (Kearney et al., 2011) about the Caernarvon diversion. It is important to note that many of the sediment diversions proposed in the Louisiana Coastal Master Plan, including the large diversions near the New Orleans area where Caernarvon and Davis Pond are located, are being designed to more efficiently transport sediment into the basin following the three criteria outlined above (CPRA, 2017). Further, the scale of these sediment diversions is different; Mid-Breton and Mid-Barataria sediment diversions are being designed to convey up to 75,000 cfs (2124 $m^3 s^{-1}$) of river water, while Caernarvon and Davis Pond diversions operate at a maximum flow of 9000 and 10,650 cfs, respectively (255 and 301 $m^3 s^{-1}$, respectively) for a limited number of weeks yr^{-1} (Peyronnin et al., 2017). With regard to these caveats, the objectives of this research were to: 1) conduct an analysis of wetland change at the Caernarvon and Davis Pond Freshwater diversions to determine if the diversion operations were coincident with net land gain/loss and 2) compare our detailed spatial and temporal analysis with field measurement studies as well as other published remote sensing analyses.

2. Materials and methods

2.1. Study area

The Caernarvon River diversion is located downriver of New Orleans on the east bank of the Mississippi River near Caernarvon, Louisiana (Fig. 1). The diversion has been in operation since August 1991. The diversion has a maximum discharge rate of 226 $m^3 s^{-1}$, and an average discharge of 21 $m^3 s^{-1}$ (Lane et al., 2006). It should be noted that the volume of river water diverted through the Caernarvon structure is much lower, by an order of magnitude or more, compared to the volume of river water that flowed into the estuary before the levees were built. (Welder, 1959; Kesel, 1988; Day et al., 2016a; Day et al., 2016b), with peak flows ranging from 5000 to 10,000 $m^3 s^{-1}$ (Davis, 2000). The river water flows into Big Mar, a 10 km^2 pond formed by a failed impoundment (Fig. 1), which has mostly filled in with sediments from the diversion and hurricane wrack over the years (Lopez et al., 2014) There is considerable overland flow as diverted river water is directed to the open waters of Breton Sound (Snedden et al., 2007). There are about 1100 km^2 of fresh, brackish, and saline wetlands interspersed with shallow open waterbodies in the Breton Sound estuary. The diurnal tidal range in Lake Leary south of Caernarvon is about 10 cm, less than the astronomical tidal range of about 0.3 m, due to distance from the coast.

On August 29, 2005, hurricane Katrina passed over southeastern Louisiana with winds in excess of 200 km h^{-1}. The hurricane traversed the Breton Sound estuary producing a 6-m storm surge over much the estuary, causing massive disturbance to the extensive wetlands in the upper basin (Day et al., 2007; Barras et al., 2008). On September 23–24, 2005, hurricane Rita passed south of Breton Sound and led to further disturbance (Barras, 2007a; Barras, 2007b) further impacted this coastal system.

The Davis Pond Freshwater Diversion is located on the west bank of the Mississippi River, ~24 km upstream of New Orleans (Fig. 1) that delivers river water into the upper Barataria Basin. Mean discharge is ~36 $m^3 s^{-1}$ with a maximum discharge of ~300 $m^3 s^{-1}$ to the receiving basin. Geologic subsidence in the Davis Pond area is about 0.9 cm yr^{-1} (CPRA, 2017; Nienhuis et al., 2017; Jankowski et al., 2017). Rates of

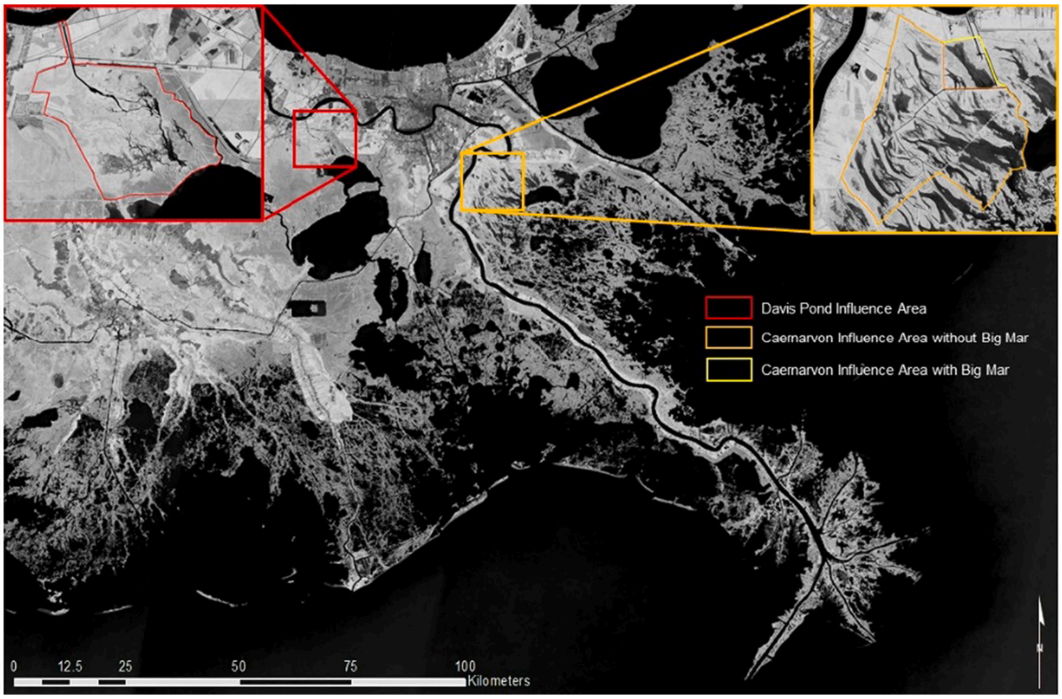

Fig. 1. Location of the Davis Pond diversion (red outline) and the Caernarvon diversion (yellow outline) in the Mississippi River delta. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

vertical accretion in the Mississippi River Delta are also spatially variable, but the delta-wide median value is ~11 mm yr^{-1} (Jankowski et al., 2017).

The ~38 km^2 receiving basin at Davis Pond is bounded by guide levees on three sides and at the south, water flows into Lake Cataouatche. From there, water flows through a series of shallow lakes and marshes, across Barataria Bay and eventually reaches the Gulf of Mexico ~80 km to the south. The diurnal tidal range in Lake Cataouatche is about 10 cm. Construction of Davis Pond diversion was completed in 2002 (http://www.mvn.usace.army.mil/About/Projects/Davis-Pond-Freshwater-Diversion/). Freshwater diversions such as Davis Pond are primarily designed and operated to regulate salinity rather than to build land, however they do transit a considerable amount of sediment. This has led to the emergence of a new crevasse splay deposit at the mouth of the Davis Pond inflow channel (Keogh et al., 2019). Mouth bar deposits and fringing marsh have begun to fill in previously open water ponds. Today, wetlands in the receiving basin are dominated *by herbaceous species (Sagittaria lancifolia, Colocasia esculenta, Mikania scandens, and Polygonum punctatum)* with black willow (*Salix nigra*) colonizing higher elevation islands (Gardner and White, 2010).

2.2. Methodology

2.2.1. Spatial data-background

It is vitally important, especially more so today with the online access of numerous data sets, that potential users understand the purpose and limitations of data sets in order to properly apply them. To illustrate this, consider the case outlined in Fig. 2. The persistent change dataset records the last time a change occurred and then remains persistent throughout the remainder of the observation period. This is to say, that when calculating land area values by re-coding the persistent change data, those numbers would not include the water area present in t3 and t4, although these changes did indeed exist (Fig. 2). Instead, trend data should be calculated using the individual dates of land area classification (doi:https://doi.org/10.5066/P99LJJZZ). The persistent change data is not appropriate for temporal trend calculations as there is an absence of non-persistent changes, which may impact land area change trends and obscure the associated uncertainty. Land change can be particularly problematic when looking at low slope/ flat landscapes where small changes in water depth can submerge or expose land. In that case, the land did not disappear, but it was just submerged due to changes in water level. In addition, some studies have used coarse-level data which are intended for coastwide and basin scale analyses and have inappropriately applied them to relatively small areas. In one specific case, the metadata of the persistent change data clearly state that the application for which the data was used by Turner et al. (2019) was inappropriate, leading to an erroneous conclusion. The data set linked and the metadata description is provided below: https://www.sciencebase.gov/catalog/item/5a67a8cde4b06e28e9c57150; Couvillion et al., 2017).

“Purpose: The spatial dataset outlines persistent changes only, and as such is not appropriate for representing a particular date in time, **nor is it appropriate for change rate calculation**.”

“Use Constraints: As this dataset depicts persistent changes only, **it is not appropriate for the calculation of change rates**, nor for the depiction of the landscape at one point in time. Users are advised to read the data set’s metadata thoroughly to understand appropriate use and data limitations. Users are advised to contact the author of this research with questions regarding its appropriate use. The distributor shall not be liable for improper or incorrect use of this data, based on the description of appropriate/inappropriate uses described in this metadata document. These data are not legal documents and are not to be used as such.”

“Access Constraints: This data is intended for multi-decadal coastwide and basin level analyses. It may not be appropriate for analyses at finer spatial or temporal scales.”

2.2.2. Re-analysis of land change at Davis Pond and Caernarvon

For the reasons mentioned above, we used a more appropriate and effective spatial and temporal analysis to assess the land change patterns in the vicinity of the Caernarvon and Davis Pond diversion wetland areas and sought to confirm our findings citing field studies and other remote sensing studies (Couvillion et al., 2018). There are essentially two options to more appropriately answer this question in small (relative to coastwide and basin scale) and fragmented marsh areas where there is a mixture of vegetated marsh and open water: Option 1). Use high resolution data such as aerial imagery. A drawback of this approach is that temporal resolution is generally greatly reduced in these types of datasets, which is particularly important in areas exhibiting high water-level variation such as river diversion receiving areas. Option 2). Use moderate spatial resolution data with frequent temporal coverage, but rather than creating categorical or ‘thematic’ classifications of land and water, one can generate continuous estimates of the sub-pixel composition. In other words, for each pixel, one can estimate the composition (e.g. 70% land, 30% water). This mitigates some of the issues brought about by binary classification of land or water, related to spatial resolution. We applied the option 2 technique to the same areas as in Turner et al. (2019). Additionally, Turner et al. (2019) specifically excluded Big Mar from their Caernarvon diversion influence area. For the purposes of comparison, we present findings both excluding and including Big Mar, the initial receiving location of the river diversion waters at Caernarvon.

For this analysis, we used Landsat 5 and 8 imagery over a 1984–2019 observation period to ensure consistency in spatial resolution and record completeness of Surface Reflectance data and these were generated using the Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS) (U.S. Geological Survey, 2019a; U.S. Geological Survey, 2019b).

Cloud recognition and exclusion was conducted using the “sr_cloud_qa” and “pixel_qa” bands available in the Landsat Surface Reflectance products. The collection of all Landsat images was first filtered to include only images in which the project area contained 5% or less clouds as discerned by the pixel quality flags. A modified Normalized Difference Water Index (mNDWI) was calculated for each selected

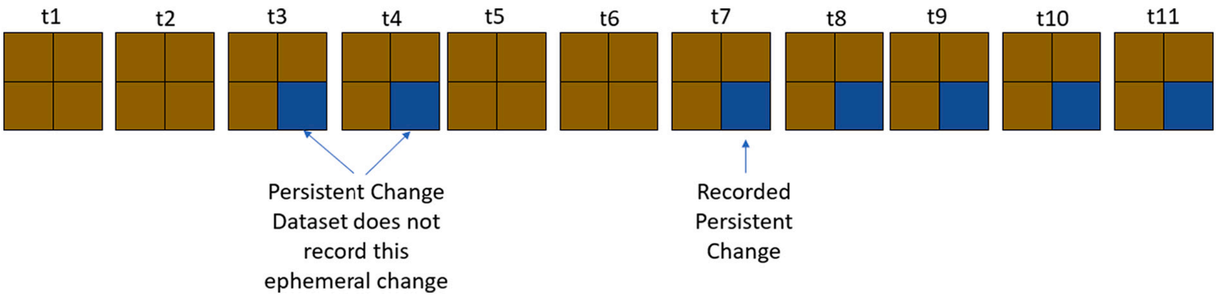

Fig. 2. Illustration demonstrating how persistent change data does not reflect ephemeral changes over time and hence is inappropriate for trend analyses as in the Couvillion et al. (2017) data set.

image in a project dataset (Xu, 2006). A Normalized Difference Vegetation Index (NDVI) was also used, as it is particularly informative with regards to the presence/absence of vegetation (Rouse et al., 1973).

To correct for aquatic vegetation, an aquatic vegetation possible mask was created by querying pixels that contained a variable NDVI signal as well as a variable mDNWI signal during a given year. The resulting mask was then used in conjunction with a spectral signature of aquatic vegetation. Linear Spectral Unmixing was then used to estimate the portion of each pixel comprised by aquatic vegetation. Linear Spectral Unmixing (LSU) was used to determine the relative abundance of classes in a given pixel of multispectral imagery based on the classes' spectral characteristics. In this case, LSU was used to determine the relative abundance of land, water, floating aquatic vegetation and submerged aquatic vegetation in each pixel. In this way, sub-pixel compositions could be quantified, thereby alleviating some of the issues of using coarse spatial resolution data in a small study area.

Endmembers, or spectral values indicative of pure classes were developed using high-resolution (1-m) aerial imagery-based land/water classifications for 2005, 2008, and 2016 in or near the areas of interest to this analysis. Image pairs were chosen to match dates as closely as possible among the aerial imagery and Landsat imagery. The composition of 30-m cells was determined by the high-resolution imagery, and compositions were binned into intervals of 1%. The endmembers for land and water in this case were determined using the X and Y intercepts of the linear fit of these data. The values of these lines at 0% water and 100% water were -0.344 and +0.203 respectively in 2005/2008 and -0.325 and+0.199 in 2015/16. These two sets of endmembers were used for Landsat 5 and Landsat 8 respectively. Coastwide Reference Monitoring System high-resolution land/water classifications (Couvillion et al., 2018) were designated as "truth" and Landsat derived percent land estimates were compared to these datasets at 390 Coastwide Reference Monitoring System (CRMS) sites. The CRMS system is a network of 390 permanent stations across the Louisiana coastline where a variety of physical and biological measurements have been conducted for the past 17+ years. The program was first conceived in 2003 and described by Steyer et al. (2003). Fractional estimates were produced from Landsat imagery for time periods that most closely matched the date of acquisition (DOA) for the 2005, 2008, and 2015/16 CRMS products. The Landsat derived datasets were summarized in the CRMS 1-km analysis boundary and compared to aerial imagery-based percent land estimates from CRMS data. The resulting comparisons are shown in Fig. 3. A 1:1 reference line is included for comparison.

The root mean squared error (RMSE) of these comparisons ranged from 11.88% to 14.04%. The bias ranged from +7.33% to +12.03% indicating that at most sites, particularly in those with land composition values exceeding 20% land, the Landsat-derived percent land generally overestimates land compared to the CRMS analyses. While the overestimation of land by Landsat derived products is important to quantify,

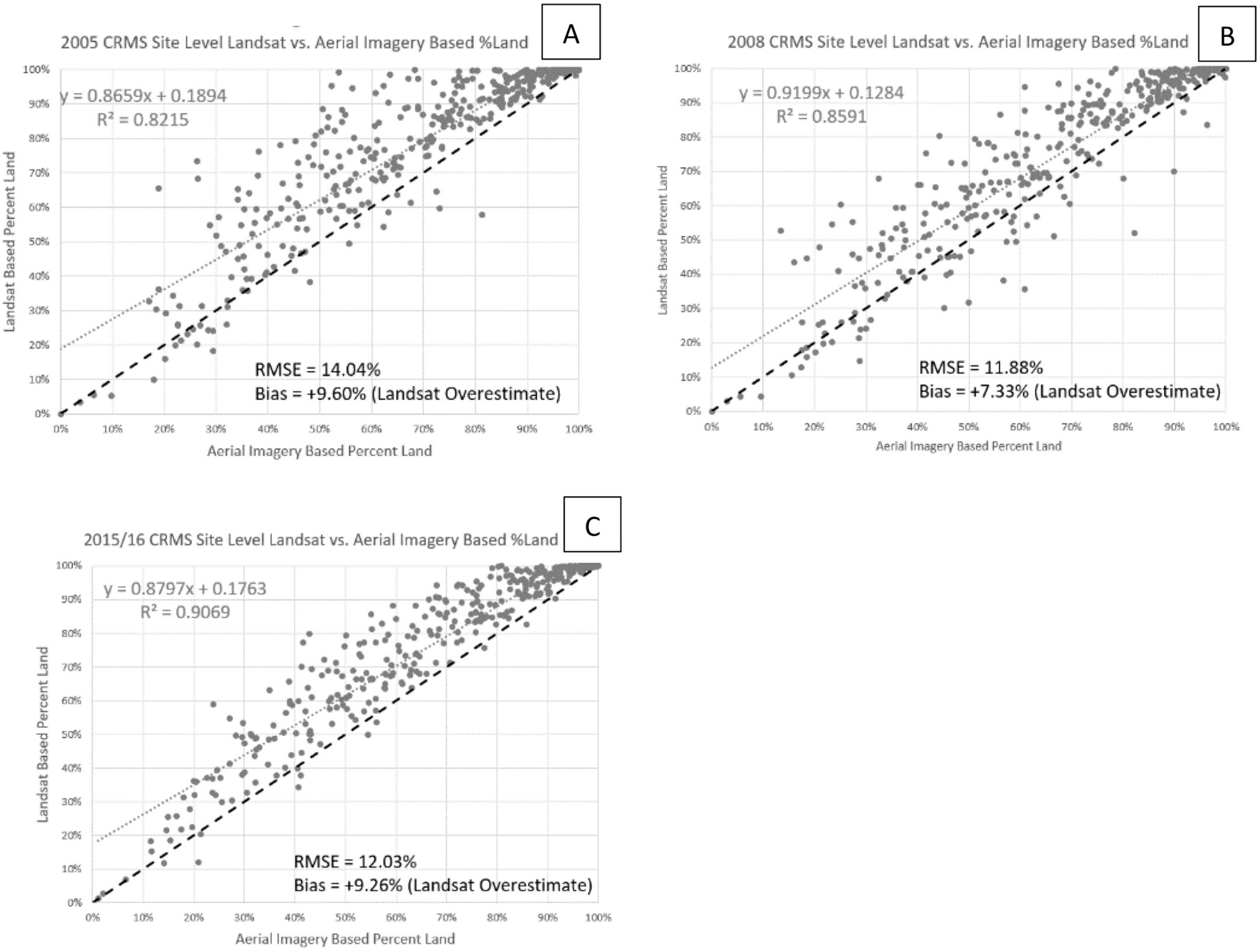

Fig. 3. Comparison between percent land as assessed from high-resolution, aerial imagery based CRMS analyses and Landsat based fractional estimates in A) 2005, B) 2008, and C) 2015 in southwest Louisiana and 2016 in southeast Louisiana at CRMS sites.

it is important to note that the pattern of overestimation of land is relatively consistent through time, indicating change analyses and the trends derived from them are still informative as they consistently overestimate land through time.

The function of change in land area over time was fit using penalized regression splines. This method fits land change as a set of polynomials in a piecewise-continuous fashion. Trends computed from this spline technique are smoothed, and as such, generalize trends through time. The complexity of the spline, as determined by the dimensionality of its basis function, was set to a maximum of 16, but its final value was determined by cross-validation to prevent overfitting. The goodness-of-fit is described by the R^2 statistic. Effective degrees of freedom (edf) can be interpreted as being related to the degree of the polynomial order of the spline (edf = 1 is linear, edf = 2 is quadratic, etc.). The uncertainty of the finite differences was calculated by posterior simulations. Each fitted model was simulated 10,000 times.

3. Results and discussion

3.1. Davis pond diversion

The resulting hyper-temporal analysis of the Davis Pond influence area reveals a dynamic environment which has experienced dramatic change over the pre and post diversion implementation time period. Fitted values indicate a land area of 32.55 +/− 0.62 km^2 in 2002 when diversion operations began (Table A1, Fig. 4). Land area values indicate a slight increase from 2002 to 2005, followed by a decrease through 2010, however all these changes are within the uncertainty range of this analysis. Of note, however, is the latest land area estimate in 2019 of 35.96 +/− 0.77 km^2 (Table A1, Fig. 4). The confidence intervals of the 2002 and 2019 land areas indicate the land area increased between 2.0 and 4.8 km^2 over the 17-year span." (Table A1, Fig. 4). In particular, the land increase from 2008 to 2019 is coincident with the majority of diversion operations. A decadal field soil sampling study of 130+ sites in Davis Pond completed in 2007 and repeated in 2018, found a doubling in bulk density in wetland soils in areas of river water influence over this time period (Kral et al., 2012; Spera et al., 2020). This increase in bulk density was attributed to deposition of inorganic river sediment. This increased mineral content was also confirmed by a short-term accretion study that calculated that Davis Pond received 106,800 metric tons of sediment in winter/spring of 2015. This study found that 44% of the sediment was retained in the basin, while in the summer/fall 2105, with a loading of 35,900 metric tons of sediment, 81% was retained in the basin (Keogh et al., 2019). Clearly, this diversion, designed primary for water conveyance, is receiving and depositing substantial sediment loads from the river as evidenced by the agreement between the field measurement studies and the remote sensing analysis.

3.2. Caernarvon diversion

The Caernarvon Freshwater Diversion influence area land area change analysis is less definitive. Fitted values indicate a land area of 51.39 +/− 1.61 km^{-2}. in late 1991–1992 when the diversion began operation (Table A2, Fig. 5a). Land area estimates in 2019 are 51.05 +/− 2.54 km^{-2}. (Table A2, Fig. 5a). The confidence intervals of the 1992 and 2019 land areas indicate net land area changed between −4.49 and 3.81 km^2 since diversion operations began. As the confidence limit spans zero (−4.49 – +3.81 km^2), we cannot statistically conclude

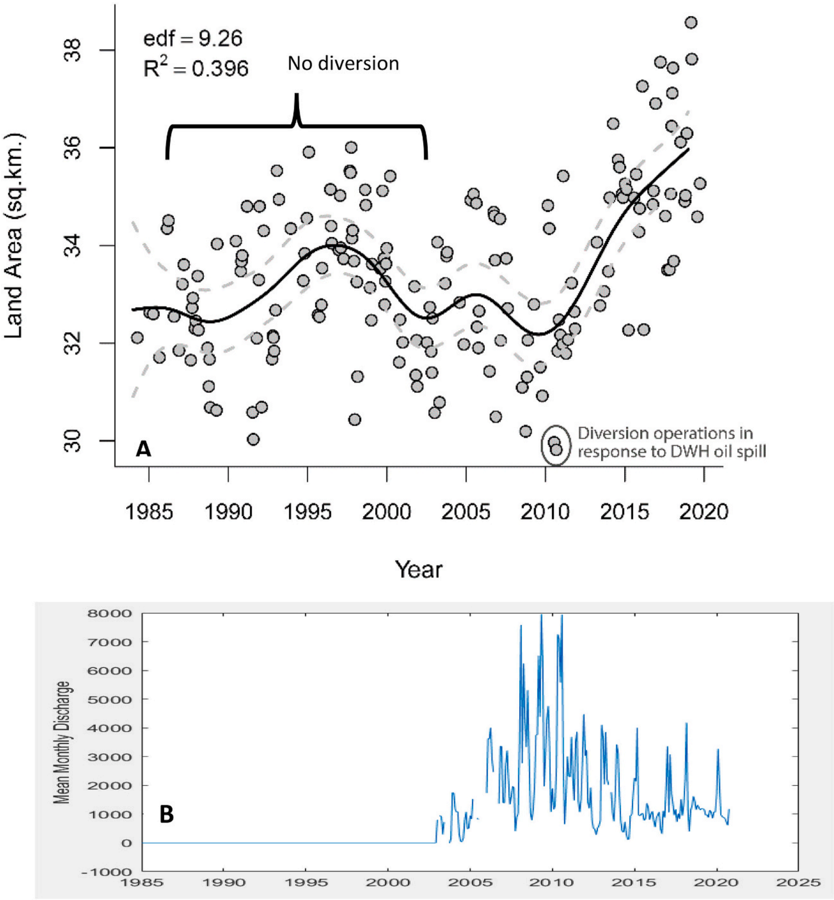

Fig. 4. A) Mean land area change in the influence area of Davis Pond Diversion with plotted uncertainty. The bracket indicates the land change prior to the operation of the diversion B) mean monthly discharge of the Mississippi River into the Davis Pond Diversion wetlands aligned with time axis for Fig. 4A.

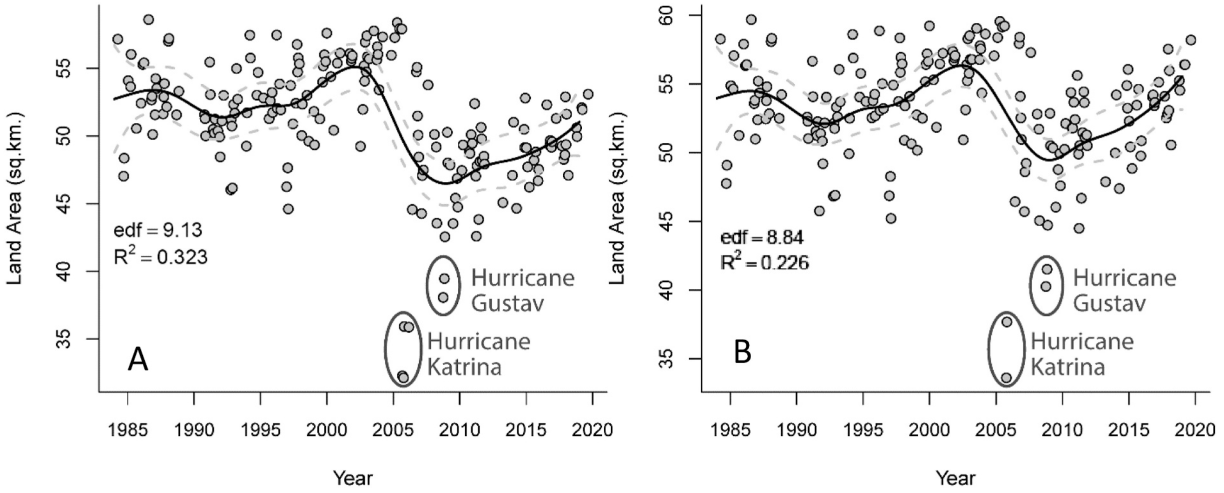

Fig. 5. Land area change in the variable influence areas of Caernarvon Diversion. The influence area for graph A) excludes Big Mar while B) includes Big Mar in the analysis.

that there was gain nor loss during this time period (Table A2, Fig. 5a). The previous analysis, however, is for the diversion influence area used in Turner et al. (2019), which excluded Big Mar. Big Mar is situated in the diversion's immediate outfall and as noted above, has experienced subaerial land gain since 2005 due to sediment deposition (Lopez et al., 2014). Whether Big Mar should be included in the diversion influence area does not seem reasonably debatable, as it clearly falls within the immediate diversion outfall areas. We then proceeded to run a land area change analysis, including Big Mar, to illustrate the difference its appropriate inclusion would impact this land change analysis (Table A3, Fig. 5b). When Big Mar is included in the analysis, the Caernarvon Diversion influence area land area change analysis indicates a land area of 52.09 +/− 1.49 km^2 in late 1991–1992, and 55.54 +/− 2.41 km^2 in 2019 (Table A3, Fig. 5b). When including Big Mar, the confidence limit still spans zero (−0.45 ±7.35 km^2), and as such, we cannot conclude that there was either gain or loss during this time period (Table A3; Fig. 5b). However it is notable that 94% of the confidence interval are in the positive range (above zero) compared to just 45% of the confidence interval in the positive analysis excluding Big Mar. There have been extensive studies of the upper Breton Sound Basin that show rapid nutrient uptake with most nitrate removed from the water column through denitrification (Gardner and White, 2010; Upreti et al., 2021; Bowes et al., 2022), enhanced wetland productivity (Day et al., 2013) and enhanced vertical accretion (Lane et al., 2006).

3.3. Summary analysis

Our spatiotemporal analysis, complete with statistical uncertainty, demonstrate a land *increase* in the Davis Pond diversion ponding region in opposition to a previously published study (Turner et al., 2019) that

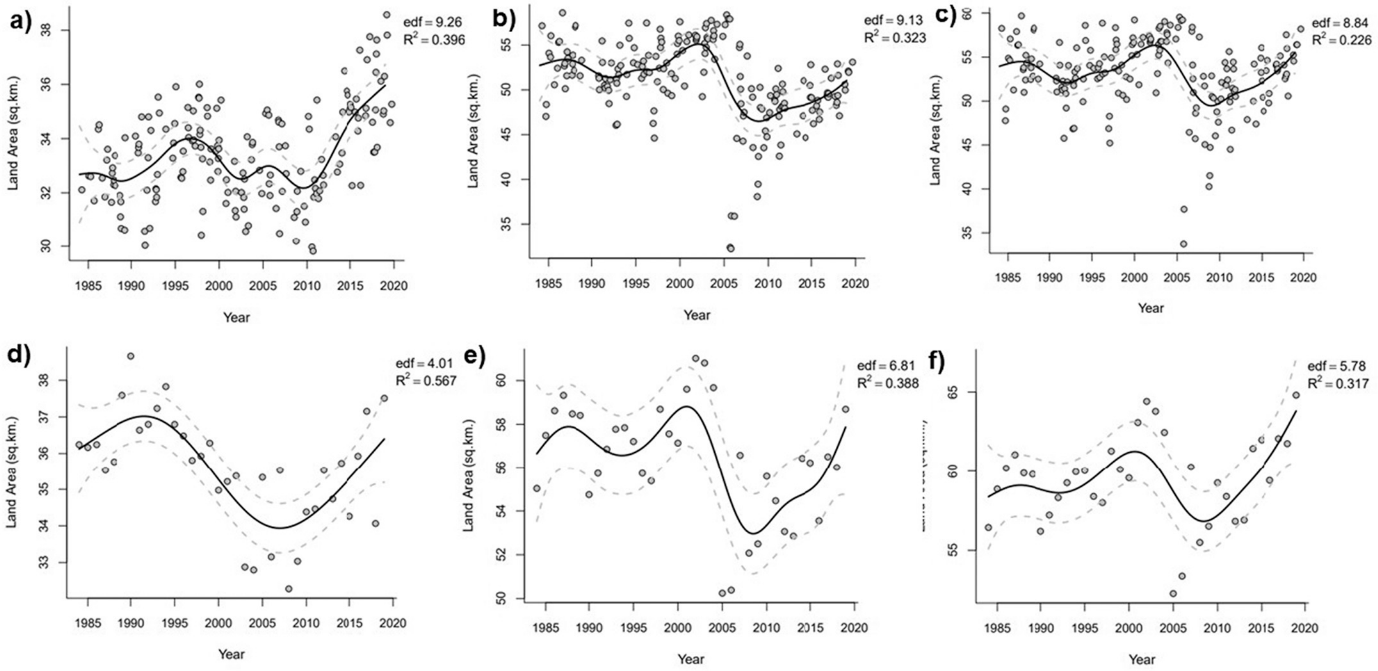

Fig. 6. A comparions of land area change in receiving wetland areas of the diversions as estimated from the fractional wetland area estimation techniques described in this paper (A-C) and the Global Surface Water Explorer (Pekel et al., 2016) (D-F). A&D) Davis Pond Influence Area, B&E) Caernarvon Influence Area excluding Big Mar, C&F) Caernarvon Influence Area including Big Mar.

inappropriately used the persistent change data set and reported a *loss* of land. In addition, our analysis for the Caernarvon diversion influence demonstrates *no statistically detectable change* with trend lines moving up and down through time within the region of uncertainty, while Turner et al. (2019) reported *land loss*. Given the issues with the inappropriate application of the dataset by Turner et al. (2019), and this more appropriate analysis, we can assert that the land area change results reached by Turner et al. (2019) were an erroneous conclusion.

To further validate our findings, we compared our results (Fig. 6a, b, c) with those from the Global Water Explorer (Pekel et al., 2016) that recorded water surface area changes from 1984 to 2015 for almost 90,000 km^2 globally including the Davis Pond and Caernarvon study areas (Fig. 6 d, e, f). After we plotted the data from Pekel et al. (2016) for our study areas, the patterns of land area change between the two studies are very similar. The density of our temporal observations in our study is much higher, providing a more detailed picture of land change over time, however the trends are the same. Neither our study nor that from Pekel et al. (2016) shows a statistically significant net land loss as a result of river diversion operations.

We also compared our results to those of the recent paper Mo et al. (2020) and the Deltares Aquamonitor mapping tool. Mo et al. (2020) mainly reported NDVI values for areas affected by hurricanes including the Breton Sound area. The area of intermediate and brackish marshes was reported for the period 2005 only through 2010. Our analysis of wetland area change was from 1985 until 2020. Our pattern of wetland area change over time was similar to that of Mo et al. for the 5-year period 2005–2010 they report. However, wetland area increased after 2010 and by 2020 had reached pre-Katrina levels. Our results were also similar to those of the Deltares Aquamonitor tool (https://www.deltares.nl/en/software/aqua-monitor/) which demonstrates the same pattern of wetland land change over time as our study. The similarity of our results to those of the three independent studies over time supports our conclusion that there was a net gain in wetland area at Davis Pond and no statistically significant change at Caernarvon.

This analysis clearly highlights an issue with land change analyses in wetland regions conducted in low-slope coastal areas heavily influenced by fluctuating water levels. It is clear that prior to diversion operation at Davis Pond, there is substantial fluctuation in land area due to climate variability in precipitation and resulting water levels (bracket; Fig. 4A). In this case, it is not the fact that land is being created and lost with time, but rather submerged or exposed through hydrologic variability. This effect of water level on "land area" is even more stark at Caernarvon, as the storm surge from Hurricanes Katrina and Gustav caused apparent immediate land loss (small circles; Fig. 5A, B). These data could be incorrectly interpreted as substantial, instantaneous land loss if not taken in context of the entire timeline. However, much of this land change is simply due to temporary flooding over the land for some period post hurricane (Fig. 5A, B). A similar trend can be seen in Davis Pond when, during the Deepwater horizon oil spill, the diversion was operated at high flow for substantial time (small circles) in an attempt to prevent oil from moving into the coastal bays (Fig. 4A). However, these events are clearly anomalies in the trend analysis because the land is submerged, not eroded or lost.

4. Conclusions

As more and more coastlines are monitored using remote sensing, we have outlined reasons that spatial land change analyses can be fraught with error, especially within the context of fluctuating hydrology in coastal wetlands. We demonstrated that the Davis Pond diversion influence area has experienced net land gain over time since diversion operations began (+3.42 km^2 (range + 2.02 +/− 4.81 km^2.). This gain has occurred even though Davis Pond was not designed as a de facto sediment diversion. This observation was corroborated by 2 field studies a large spatial field study that found substantial river sedimentation within the ponding area. We suggest that the Davis Pond Diversion is a good indicator of how coastal wetlands respond to these relatively small, infrequent river diversions, because these receiving wetlands are protected from hurricane storm surge and other confounding factors due to distance from the coast. These other factors led to the high variability seen in the Caernarvon diversion data, which led to the conclusion of no statistical land change over time within the confidence limits, due to the expressed high variability. This study demonstrates that repeated observations from satellite imagery are an effective means of establishing pre-construction change rates and enable post-construction monitoring of benefits for coastal restoration projects, especially if corroborated with other remote sensing studies as well as studies taking physical measurements. Results from this study should serves as a cautionary tale that, while more and more datasets are available online and available to all, users of third-party data sets should carefully read the documentation to mitigate occurrences of inappropriate application.

CRediT authorship contribution statement

John R. White: Conceptualization, Writing – original draft. **Brady Couvillion:** Conceptualization, Methodology, Formal analysis, Writing – review & editing, Visualization. **John W. Day:** Conceptualization, Writing – original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecoleng.2022.106819.

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